Scaling digital radiographs for templating in total hip arthroplasty using conventional acetate templates independent of calibration markers.

CJ Brew, PM Simpson, SL Whitehouse, B Donnelly, RW Crawford, MJW Hubble.

Abstract

We describe a scaling method for templating digital radiographs using conventional acetate templates independent of template magnification without the need for a calibration marker.

The mean magnification factor for the radiology department was determined (119.8%, range117%-123.4%). This fixed magnification factor was used to scale the radiographs by the method described. 32 femoral heads on postoperative THR radiographs were then measured and compared to the actual size. The mean absolute accuracy was within 0.5% of actual head size (range 0 to 3%) with a mean absolute difference of 0.16mm (range 0-1mm, SD 0.26mm).

Intraclass Correlation Coefficient (ICC) showed excellent reliability for both inter and intraobserver measurements with ICC scores of 0.993 (95% CI 0.988-0.996) for interobserver measurements and intraobserver measurements ranging between 0.990-0.993 (95% CI 0.980-0.997).

Key Words: Total hip arthroplasty, digital radiograph templating

Introduction

Total hip arthroplasty is successful in relieving pain and improving function in patients suffering from significant hip arthritis. However problems can occur if components are malpositioned or incorrectly sized. Preoperative templating prior to performing total hip arthroplasty would therefore help minimize these risks.

Oversizing the acetabular component may result in psoas impingement or acetabular fracture especially when using uncemented cups [1] or excessive bone removal when using cemented cups. Templating of uncemented femoral stems minimises the risk of oversizing and therefore femoral fracture [2] or loosening and subsidence if undersized [3]. Templating of cemented stems ensures the presence of a suitable cement mantle and may also alert the surgeon to potential problems caused by narrow femoral canals as well as helping to ensure the correct restoration of femoral offset and of leg lengths.

Preoperative templating also alerts the surgeon to any potential need for unusual sized components that may require preordering. This is especially the case with the advent of digitilised radiographs where the scale can mislead the surgeon into believing standard size components will suffice. Many hospitals are now storing less preordered stock with implants being brought in on a case by case basis, highlighting the importance of accurately assessing the required implant sizes preoperatively.

Traditional preoperative templating involves overlaying an analogue radiograph with the standard manufacturers acetate templates that are magnified by 15%-

20% to allow for the magnification that occurs during image acquisition. Previous reports have shown that digital acquisition of images tends to reduce the average magnification of the film thereby reducing the accuracy of standard manufacturers templates when used with hard copies of digital radiographs [4].

Most orthopaedic units are now using the picture archiving and communications systems (PACS) instead of conventional radiographs. This has resulted in traditional hard copy radiographs being unavailable for use with the standard acetate templates. Electronic templating software can be used to template these digital images but this is costly to purchase, requires training in its use and requires every radiograph to be taken in the presence of a calibration marker of known size placed in the same plane as the hip joint.

However many orthopaedic departments do not have electronic templating software available, nor do they have radiographs with calibration markers available as standard. Therefore accurately templating digital radiographs, in the absence of a calibration marker can be difficult.

The aim of this paper is to describe a method that allows scaling of the digitilised on screen radiograph to the manufacturers standard acetate template independent of the magnification of the template and without the need for the presence of a calibration marker.

Materials and Methods.

Calculating the average magnification factor of radiography department

The femoral head sizes on 32 post operative total hip replacement digital radiographs taken using a Philips Optimus Digital Diagnost System™ according to a standard protocol using a focus film distance (FFD) of 130cm were measured and compared to the known size obtained from operative records (range 22.5-40mm heads). These measurements were repeated at a two week interval to give a reproducible average magnification factor of 119.8% (range117.0%-123.4%). Standardisation of FFD must be agreed with the radiology department and must be used when performing all future preoperative hip radiographs that are to be used for templating in order to minimise variation in the average magnification factor of the department.

Scaling method

Scaling of a digital radiograph to an acetate template utilizes the software tools available on most PACS systems that allow lines of known length to be drawn on the screen and the ability to manipulate the on screen image magnification.

An arbitrary line is drawn on the acetate template ruler. The length of this line is then increased by the same factor as the mean magnification factor of the radiography department and a line of this new length is drawn on the screen image. The magnification of the image which includes this line is manipulated until the line on the screen is the same length as the line on the acetate template ruler. Once the two lines are of equal length the acetate is scaled to the digital radiograph and can now be used for templating in the usual manner. This technique is independent of the magnification of the template.

For example in this study an arbitrary 30mm line was marked on the ruler of a standard (20% magnification) Exeter femoral acetate template (Stryker® Orthopaedics). A 36mm line (19.8% longer) was drawn on the screen image using the PACS (Agfa Impax™ Version 6.3.1) computer software (Figure 1(a)). The acetate was held against the screen and the image manipulated using the magnification tool (provided as standard in the computer software) until the digital 36mm line measured the same length as the 30mm line on the acetate ruler (Figure 1(b)). When the two lines are equal the on screen radiograph is scaled to the acetate template and which can now be used for templating in the conventional manner (Figure 1 (c)).

The fundamental principal underlying this scaling method is that the arbitrary length of the scaling line drawn on screen has to be increased by the same magnification factor of the x-ray image over which it is drawn. If this is not done an over-sizing error will occur.

To test the accuracy and the intra and interobserver reliability of this scaling method thirty two postoperative radiographs were scaled in a random order on two separate occasions by 4 observers. The femoral head sizes were measured using the ruler on the Exeter femoral acetate templates and the measured head size was then compared to the known femoral head size.

Statistical Analysis.

The data was analysed using SPSS for Windows version 12.0 (SPSS Inc., Chicago, Illinios). Intraclass correlation coefficient (ICC) was used to test the reproducibility of this technique using intraobserver and interobserver measurements. This is on a scale of 0-1 with 1 being the best reproducibility.

Descriptive statistics were used to calculate the mean absolute difference in millimeters between the measured and actual head sizes as well as a mean absolute accuracy expressed as a percentage difference between measured and actual head sizes. The absolute values shown disregard the direction of the error and as such are more representative of true differences between measured and actual sizes when compared to relative differences that average out negative and positive values.

Results

This method of scaling the radiographs showed the measured size to have a mean absolute accuracy of within 0.5% (range 0-3%, SD 0.8%) of the actual size (Table 1). The mean difference between the actual and measured sizes of the femoral head prostheses was 0.16mm (SD 0.26mm).

Intraclass correlation coefficient (ICC) revealed excellent reproducibility for both inter and intraobserver measurements with interobserver scores of 0.993 (95% CI 0.988-0.996) for all 4 observers and intraobserver scores ranging from 0.990-0.993 (Table 2).

Discussion

Templating is not an exact science and assessing the best fit of an implant is at least partially subjective both when using templates and also intraoperatively. Decisions that are made after assessing soft tissue balance and bone quality may require the surgeon to be flexible about the initial sizes templated but it is unusual to deviate by more than one size up or down and any such occurrence should act as a warning to the surgeon to double check positioning of implants and look for possible fractures. We did not attempt to compare templated sizes with implanted sizes for these reasons. However the accuracy of templating digital radiographs does rely on accurate scaling of the radiograph to the proposed digital or conventional acetate template.

Different methods have been described to scale digital radiographs and these commonly involve placing a disc or a sphere of known size in the plane of the hip joint by either taping the coin to the lateral side of the greater trochanter [5] or embedding it in a plastic block and placing this between the thighs. [6, 7].

This method of scaling using a calibration marker was more accurate compared to other methods such as caliper measurement [7]or the use of rulers to scale lines drawn on the screen image using computer software.[5] However if the calibration marker is not positioned in the exact plane of the hip joint errors will still occur and this requires training and cooperation of the radiographers leaving many departments unable to utilize this method.

Wimsey et al showed an accuracy of 98.9% when using a coin placed between the thighs at the level of the greater trochanter to scale the radiograph but the accuracy dropped to only 93.0% when using a caliper to measure the distance between the anterior superior iliac spines on the patient and then using this measurement to scale the radiograph. Both of these techniques are more involved, costly and time consuming than the method described here and require the use of templating software. Despite this and the use of a radiographic marker in the plane of the hip joint, which is often considered the definitive method of scaling digital radiographs they appear to be less accurate than the method described.

Kulkarini et al described a more in depth method using trigonometry to calculate the appropriate size of a disc placed directly on the cassette that would accurately represent a 30mm disc placed in the plane of the hip joint in order to try and minimize positioning errors and reduce patient embarrassment. This was compared to a 30mm sphere placed between the patients thighs. Initial results showed a mean difference between the actual and measured size of 0.34mm for the sphere method compared to a difference of 0.56mm for the disc method. Our method resulted in a mean difference between actual and measured sizes of 0.16 mm thus confirming the accuracy of this technique is comparable to the established methods of scaling digital radiographs and that it is within the 1mm resolution accuracy of most templating software.

This method was also tested prior to applying a FFD of 130cm to the radiographs. The average magnification factor prior to standardization of the FFD was 115.3% (103.3-129%) and was as expected more variable. However despite this the mean absolute difference between measured and actual sizes was 1.6mm and was within 6.0% of the actual size. The accuracy improved more than ten fold after simply standardizing the FFD (Table 3).

Oddy et al measured the accuracy of templating from digital radiographs using two digital line methods and a 10 pence coin as a marker. Method 1 involved drawing a 50mm line on the screen and adjusting the image until the line matched a 50mm line on the acetate template ruler. This method oversized the coin by 14.5 %. Method 2 involved a similar 50mm line being drawn on screen and the image manipulated until it measured the same length as 50mm on a normal ruler. The size of the coin was then measured with both the ruler on the acetate template and a normal ruler. This resulted in a difference of 0.5% from the true size using the acetate ruler and a mean oversizing of 16.7% when measured with the normal ruler. These methods failed to accurately reproduce the actual size of the coin because they did not take into account the magnification of the image over which the lines were drawn.

If the image is usually magnified between 15% and 20% then the line used for scaling also needs to be increased by the same amount or scaling will tend to oversize the object. This explains why when the coin was measured with the 20% magnified acetate ruler the accuracy improved and why method 1 resulted in significant oversizing.

Heinert et al have recently described a method of scaling digital radiographs without the use of radiographic markers by measuring the distance from the x-ray source to the object (focus object distance, FOD) and the distance from the source to the x-ray cassette (focus film distance, FFD). Using the following equation: magnification =FFD/FOD the image magnification can be calculated.[8] The authors reported an accuracy of 97.2% using this method. However accurate measurement of FFD and FOD also requires the training and cooperation of the radiographers and will prolong the time the patient stays in the x-ray department which may have resource implications especially in busy hospitals. This method still depends on an estimate by the radiographer as to the plane of the hip joint so that the FOD can be accurately measured and still requires the availability of templating software to subsequently scale the radiograph.

A potential drawback with the method described is that it applies a fixed magnification factor to all radiographs unlike other scaling methods using calibration markers or non object based methods that attempt to measure the magnification of each individual radiograph. Interestingly a recent review of four methods for scaling digital radiographs using two object based and two non object based methods showed that applying a fixed mean magnification factor of 121% to all radiographs showed improved accuracy and efficiency over the other three methods [9]. These included a calibration ball placed laterally and medially to the hip joint as well as calculating the object film distance in a similar method to that described by Heinart et al.

The conclusion of the authors was that scaling digital images with calibration markers does not lead to an increased accuracy in digital templating when compared to using fixed magnification as in the traditional analogue technique. Fixed magnification technique avoids the problems and inaccuracies of positioning of calibration markers and has shown to provide clinically relevant templating accuracy of plus or minus one component size[9].

The superiority of digital templating over traditional analogue templating has yet to be proven and controversy exists with some authors believing the latter to be more accurate .[10, 11]

Inaccuracies arising during image acquisition brought about by variations in distance from the x-ray source to object (hip joint) and from source to cassette will affect the accuracy of templating no matter which method of scaling is used.

Conclusion

The method described provides an accurate, reproducible and easy to perform technique that bridges the gap between digital and analogue templating, combining the ease of use of the analogue technique with the convenience of being able to access and template digital on screen images at convenient times and locations.

Table 1. Summary of mean absolute differences between measured and actual size. Accuracies displayed as % difference between measured and actual size (SD = standard deviation).

	Observer 1	Observer 2	Observer 3	Observer 4	All Observers
Mean absolute difference (mm)	0.22	0.13	0.19	0.16	**0.16**
SD absolute difference (mm)	0.41	0.42	0.40	0.45	**0.26**
Mean absolute accuracy (%)	0.7	0.4	0.6	0.6	**0.5**
SD absolute accuracy (%)	1.3	1.3	1.3	1.6	**0.8**

Table 2. Intraclass correlation coefficients (ICC) for inter and intra observer reliability with 95% confidence intervals.

	Observer 1	Observer 2	Observer 3
Observer 1	0.993 (0.985-0.996)		
Observer 2	0.995 (0.989-0.997)	0.993 (0.985-0.997)	
Observer 3	0.994 (0.988-0.997)	0.997 (0.995-0.999)	0.990 (0.980-0.995)
Observer 4	0.992 (0.984-0.996)	0.990 (0.979-0.995)	0.991 (0.981-0.995)
Interobserver reliability for all 4 observers	0.993 (0.988-0.996)		

a) b)

c)

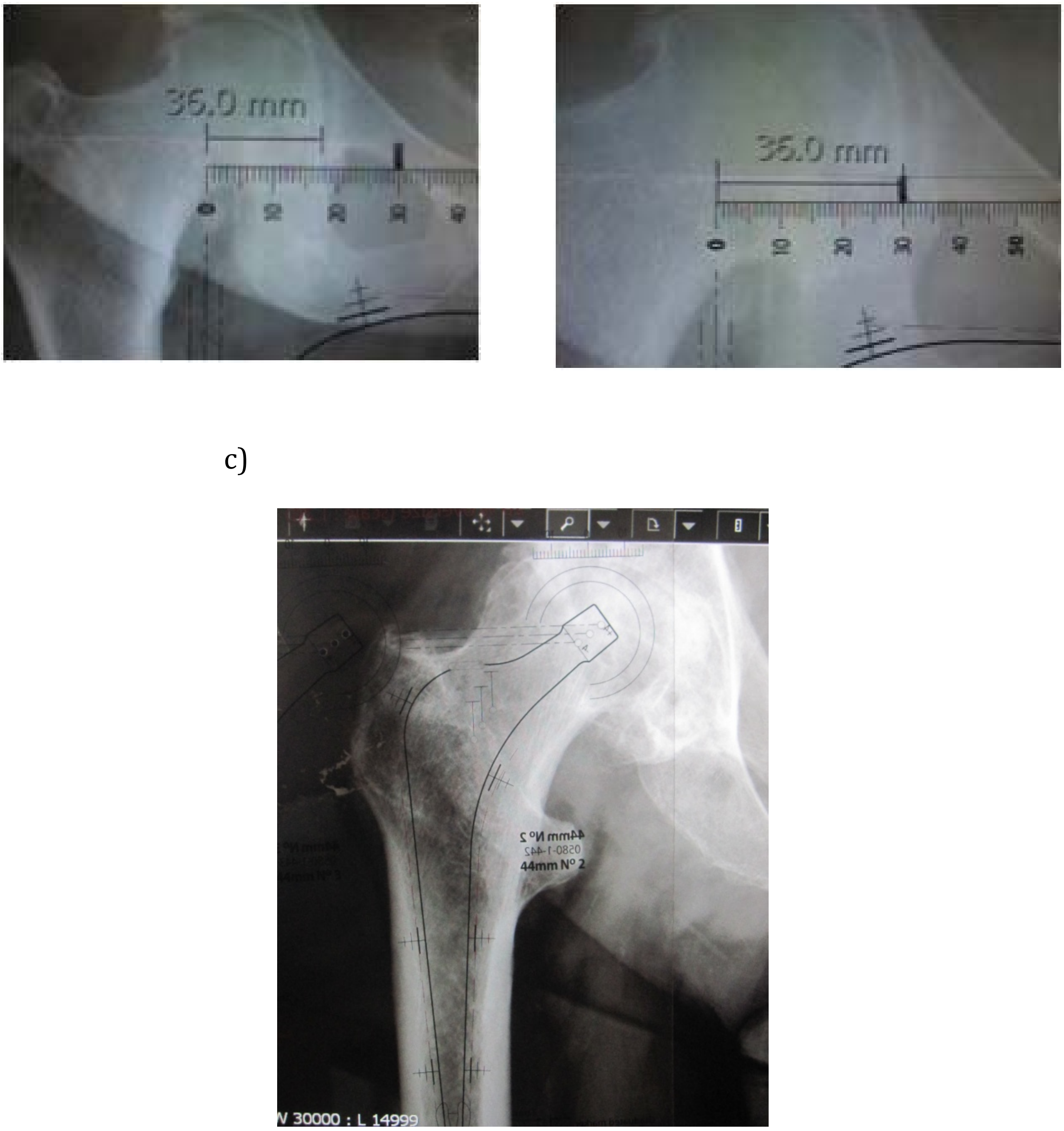

Figure 1. An arbitrary 30mm line is marked on the acetate template ruler and a line 36mm (20% longer to account for image magnification) is drawn on the on screen image using the computer software (a). Using the magnification tool the on screen image is enlarged until the two lines are of equal length (b). The radiograph is now scaled to the acetate template which can then be used for preoperative templating in the usual manner (c).

Reference List

1. O'Sullivan M, Tai CC, Richards S, Skyrme AD, Walter WL, Walter WK. Iliopsoas tendonitis a complication after total hip arthroplasty. J Arthroplasty 22(2): 166, 2007

2. Schwartz JT, Jr., Mayer JG, Engh CA. Femoral fracture during non-cemented total hip arthroplasty. J Bone Joint Surg Am 71(8): 1135, 1989

3. Aldinger PR, Jung AW, Pritsch M, Breusch S, Thomsen M, Ewerbeck V, Parsch D. Uncemented grit-blasted straight tapered titanium stems in patients younger than fifty-five years of age. Fifteen to twenty-year results. J Bone Joint Surg Am 91(6): 1432, 2009

4. White SP, Shardlow DL. Effect of introduction of digital radiographic techniques on pre-operative templating in orthopaedic practice. Ann R Coll Surg Engl 87(1): 53, 2005

5. Oddy MJ, Jones MJ, Pendegrass CJ, Pilling JR, Wimhurst JA. Assessment of reproducibility and accuracy in templating hybrid total hip arthroplasty using digital radiographs. J Bone Joint Surg Br 88(5): 581, 2006

6. Kulkarni A, Partington P, Kelly D, Muller S. Disc calibration for digital templating in hip replacement. J Bone Joint Surg Br 90(12): 1623, 2008

7. Wimsey S, Pickard R, Shaw G. Accurate scaling of digital radiographs of the pelvis. A prospective trial of two methods. J Bone Joint Surg Br 88(11): 1508, 2006

8. Heinert G, Hendricks J, Loeffler MD. Digital templating in hip replacement with and without radiological markers. J Bone Joint Surg Br 91(4): 459, 2009

9. Franken M, Grimm B, Heyligers I. A comparison of four systems for calibration when templating for total hip replacement with digital radiography. J Bone Joint Surg Br 92(1): 136, 2010

10. Iorio R, Siegel J, Specht LM, Tilzey JF, Hartman A, Healy WL. A comparison of acetate vs digital templating for preoperative planning of total hip arthroplasty: is digital templating accurate and safe? J Arthroplasty 24(2): 175, 2009

11. The B, Diercks RL, van Ooijen PM, van Horn JR. Comparison of analog and digital preoperative planning in total hip and knee arthroplasties. A prospective study of 173 hips and 65 total knees. Acta Orthop 76(1): 78, 2005